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LOW ALLOY STEEL

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6 Claims. (Cl. 148—31)

This invention relates to steels, and provides new and improved steels characterized by novel and commercially valuable properties.

We have discovered that the addition of columbium in amounts between 0.02% and 1% to so-called "plain carbon" and certain "low alloyed" steels effects a marked and surprising improvement in the properties of such steels. One important effect of the columbium addition is to refine the grain-size of the steel, and this grain refinement is retained and maintained even at elevated temperatures up to and somewhat above the critical range. Another effect, which is doubtless at least in part a result of the grain refinement, is the improvement of the tensile strength of many of the steels. Further, the impact strength is increased, and this improvement is marked even at subzero temperatures. There is also an increase in the resistance of the steels to rusting and hot oxidation. The deep-drawing and cold rolling characteristics of the steels are improved. The hardenability of the steels by heat treatment is somewhat decreased, and there is less distortion of the steel when it is rapidly cooled from elevated temperatures. The ratio of yield point to maximum stress is increased, the increase depending upon the columbium and carbon contents of the steels: the increase is greater in the steels having the lower carbon and columbium contents.

Steels included in our invention are those containing nickel and at least one carbide forming

metal of the group consisting of chromium and molybdenum.

Suitable amounts of columbium to be added to these steels according to the present invention are from 0.02% to 0.5%. Usually, it will not be necessary or desirable to exceed 0.5% columbium, and the most useful range is within the limits 0.05% to 0.25%. In general, the greater amounts of columbium should ordinarily be used in the steels containing the greater amounts of carbon, within the ranges specified above.

One of the most valuable properties of the columbium containing steels of the invention is that of retaining its normally fine grained structure at elevated temperatures, which property is attained without detrimentally affecting other important physical properties. The expedients heretofore customarily employed to refine the grain size of carbon and low-alloyed steels have, in most cases, either detrimentally affected the toughness of the steels, or failed to prevent coarsening of the grain size at elevated temperatures, during fabrication for instance, or both. The coarsening of the grain is considerably aggravated in a case carburizing process, and in such a process the addition of columbium to the steel is especially advantageous, as illustrated by the data in Table I which gives the experimentally determined grain number (A. S. T. M. Specification E19-33) of the cases of a series of steels after carburizing for eight hours at each of three different temperatures. In each case, the grain size of the core was smaller than that of the case.

Table I

Composition of steel (remainder iron)						Grain No. of case after carburizing 8 hours—		
Percent C	Percent Mn	Percent Si	Percent Cb	Other metals		At 925° C.	At 975° C.	At 1025° C.
				Percent Ni	Percent Cr			
0.13	0.42	0.16	None	1.25	0.44	2 to 7	2 to 6	1 to 6
0.34	0.41	0.13	None	1.34	0.47	3 to 9	3 to 8	2 to 4
0.14	0.43	0.21	0.09	1.24	0.59	4 to 8	5 to 7	3 to 8
0.39	0.43	0.12	0.07	1.27	0.61	4 to 8	4 to 8	3 to 7
0.47	0.60	0.14	0.11	1.61	0.68	4 to 8	4 to 6	4 to 7
0.17	0.41	0.31	None	3.40	1.25	3 to 8	2 to 6	1 to 6
0.32	0.38	0.18	None	3.57	1.49	4 to 7	3 to 7	2 to 4
0.14	0.36	0.16	0.03	3.45	1.46	6 to 8	6 to 8	5 to 8
0.34	0.37	0.14	0.10	3.53	1.46	4 to 6	6 to 7	3 to 8
				Percent Ni	Percent Mo			
0.18	0.50	0.22	None	1.74	0.24	4 to 7	1 to 6	1 to 5
0.31	0.42	0.09	None	1.74	0.25	8	2 to 7	2 to 8
0.15	0.44	0.23	0.09	1.72	0.22	9	9	9
0.40	0.43	0.23	0.10	1.77	0.14	9	8 to 9	8 to 9

In general, the grain refining effect is roughly proportional to the columbium content up to a certain optimum amount of columbium, which optimum content depends chiefly on the carbon content of the steel. The grain refinement of a maximum 0.1% carbon steel reaches substantially its greatest degree at about 0.1% columbium; a 0.15% carbon steel at about 0.15% columbium; a 0.35% carbon steel at about 0.18% columbium; and a 0.5% carbon steel at about 0.25% columbium. The presence of chromium, molybdenum, or vanadium reduces somewhat these optimum amounts of columbium. A moderate excess of columbium above the optimum and below the maximum specified above (1%), will not ordinarily adversely affect the properties of the steel to a serious extent.

The influence of columbium on the tensile and impact properties of the steels under consideration is indicated by the data appearing in Table II which show the experimentally determined yield point in thousands of pounds per square inch (Y. P.), maximum stress in thousands of pounds per square inch (M. S.), percentage elongation in a 2 inch gage length (El. %), and reduction in area (R. A. %), all on 0.505 inch diameter A. S. T. M. standard tensile test pieces;

bium is increased above 0.1%, the softening effect of the columbium begins to predominate, the yield point and maximum stress are decreased, and the ductility is substantially increased. As the carbon content is increased above 0.3%, and as other alloyed additions are made, the effects of columbium on the tensile properties are reduced, particularly if the steels are heat treated.

It will be noted in Tables II and III that the addition of columbium raises the impact strength of the steels, and that the improvement is greatest in the high carbon steels and those containing chromium.

As mentioned above, the addition of columbium to the plain carbon and low alloyed steels considerably increases their impact strength at sub-zero temperatures.

Table III contains impact data obtained in the manner described in connection with Table II, except that the samples under the heading "-78° C." were cooled about an hour at -78° C. in a bath of acetone and frozen carbon dioxide before testing. After cooling, the specimens were rapidly transferred from the cooling medium to the Izod machine and tested. The time required for the transfer and test was in all cases less than ten seconds.

Table III

Composition of steel (remainder iron)							Izod impact ft. lbs., at—	
Percent C	Percent Mn	Percent Si	Percent Cr	Percent Mo	Percent Ni	Percent Cb	+28° C.	-78° C.
0.21	0.4	0.3	None	None	None	None	56	4
0.14	0.4	0.2	0.6	None	1.2	0.09	79	69
0.15	0.4	0.2	None	0.22	1.7	0.09	68	70

and also the Izod impact value in foot pounds as determined on a standard Izod machine with an initial energy level of 120 foot pounds and a standard specimen one centimeter square provided with a 45° notch.

The presence of columbium substantially increases the resistance of these steels to hot oxidation and, although the columbium steels are not to be considered oxidation resistant in the sense that high chromium steels, for instance,

Table II

Composition of steel (remainder iron)							Y. P.	M. S.	El., per- cent	R. A., percent	Izod, ft. #
Percent C	Percent Mn	Percent Si	Percent Cr	Percent Ni	Percent Mo	Percent Cb					

Quenched in oil from 850° C.-900° C.; drawn in air at 150° C.-425° C.											
0.13	0.42	0.16	0.44	1.25	-----	-----	71	100	24	60	57
0.18	0.43	0.21	0.59	1.24	-----	0.09	68	103	20	66	46
0.44	0.75	0.25	0.65	1.5	-----	-----	181	204	10	35	9
0.49	0.75	0.25	0.65	1.5	-----	0.42	177	194	12	44	10
0.18	0.50	0.22	-----	1.74	0.24	-----	81	117	18	43	34
0.16	0.45	0.25	-----	1.75	0.25	0.18	55	94	26	69	77

Cooled in air from 850° C.-900° C.											
0.13	0.42	0.16	0.44	1.25	-----	-----	47	69	34	66	75
0.14	0.43	0.21	0.59	1.24	-----	0.09	60	73	30	54	79
0.44	0.75	0.25	0.65	1.5	-----	-----	105	148	12	32	4
0.49	0.75	0.25	0.65	1.5	-----	0.42	121	161	9	18	7
0.18	0.50	0.22	-----	1.74	0.24	-----	52	87	27	52	49
0.16	0.45	0.25	-----	1.75	0.25	0.18	57	77	35	69	52

It will be observed from the data of Table II that, in the steels containing up to about 0.3% carbon, the addition of up to about 0.1% columbium increases the yield point, maximum stress, and ratio of yield point to maximum stress. The ductility is only slightly affected. As the colum-

are oxidation resistant, the increase in resistance will be valuable in many uses of the steels.

The invention is based on the above-described discoveries and comprises new alloy steels and articles composed thereof, having in addition to

0.02% to 0.5% columbium, substantially the limits of composition indicated in Table IV.

Table IV

Type of steel	Composition limits (remainder iron)			
	Percent C	Percent Mn	Percent Si	Other metals
Cr-Ni	Up to 0.8	Up to 1	Up to 1	0.05 to 5% Ni, 0.25 to 2% Cr,
Mo-Ni	Up to 0.8	Up to 1	Up to 1	0.05 to 5% Ni, 0.05 to 1% Mo.

The articles of the invention include articles deep-drawn from the steel of the invention; articles having a core containing less than 0.5% carbon and a carburized case containing more than 0.8% carbon, and 0.02% to 0.5% columbium throughout, the remainder of the composition being as shown in Table IV; parts of machines and of other apparatus, required to withstand stress at moderately elevated temperatures; articles, composed of the steel of the invention, designed for use to resist impact shock at subzero temperatures; and pressure vessels, composed of the steel of the invention, designed to withstand two or three dimensional stress at subzero temperatures.

It will be appreciated that the specific examples herein are given by way of illustration, and that the invention is not limited to or by such examples.

This application is a division of our application Serial No. 87,006, filed June 24, 1936.

We claim:

1. Low alloyed steel containing carbon in an amount between 0.1% and 0.6%; manganese in an amount not exceeding 2%; silicon in an amount not exceeding 1%; at least one carbide forming metal of the group consisting of chromium and molybdenum in an amount not exceeding a total of 3%, the chromium being less than 2% and the molybdenum not exceeding 1%; 0.05% to 5% nickel; 0.02% to 0.5% columbium which imparts to said steel a fine-grained structure which persists at all temperatures up to and somewhat above the critical range; and the remainder iron.

2. Steel containing carbon in an amount between 0.1% and 0.6%; manganese in an amount

not over 1%; silicon in an amount not over 1%; 0.25% to less than 2% chromium; 0.05% to 5% nickel; 0.05% to 0.25% columbium which imparts to said steel a fine-grained structure which persists at all temperatures up to and somewhat above the critical range; the remainder iron.

3. Steel containing carbon in an amount between 0.1% and 0.6%; manganese in an amount not exceeding 1%; silicon in an amount not over 1%; 0.05% to 1% molybdenum; 0.05% to 5% nickel; 0.02% to 0.25% columbium which imparts to said steel a fine-grained structure which persists at all temperatures up to and somewhat above the critical range; the remainder iron.

4. Case carburized article having a core containing less than 0.05% carbon and a carburized case containing more than 0.8% carbon, the core and case being composed of a steel containing, aside from carbon, manganese in an amount not exceeding 2%; silicon in an amount not exceeding 1%; at least one carbide forming metal of the group consisting of chromium and molybdenum in an amount not exceeding a total of 3%, the chromium being less than 2% and the molybdenum not exceeding 1%; 0.05% to 5% nickel; 0.02% to 0.5% columbium which imparts to said article a fine-grained structure, increased ductility, and increased impact strength; the remainder iron.

5. Article used to resist, at subzero temperatures, impact shock or multidimensional stress, which article is composed of a low alloyed steel containing carbon in an amount between 0.1% and 0.6%; manganese in an amount not exceeding 2%; silicon in an amount not exceeding 1%; at least one carbide forming metal of the group consisting of chromium and molybdenum in an amount not exceeding a total of 3%, the chromium being less than 2% and the molybdenum not exceeding 1%; 0.05% to 5% nickel; 0.02% to 0.5% columbium which imparts to said article increased impact strength at subzero temperatures; the remainder iron.

6. Article subject to impact stress at elevated temperatures below 500° C. and composed of the steel defined in claim 1.

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CERTIFICATE OF CORRECTION.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 16, claim 4, for "0.05%" read 0.5%; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 9th day of April, A. D. 1940.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.